

NASA PROGRESS IN LIFE SCIENCES

by

[Hugh L. Dryden] [1964] 20p one

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N64-14866

CODE-1

TMX-51344

5th Presented at the  
Fifth Annual Lectures in Aerospace Medicine  
Brooks Air Force Base AFB, Tex.,  
February 3, 1964

INTRODUCTION

I am grateful for this opportunity to participate in the annual "Lectures in Aerospace Medicine." These lectures have come to be recognized as an outstanding forum for the exchange of information bearing on the many technological aspects of both aviation medicine and space medicine. It is gratifying to see such a large group in attendance. As one not qualified to discuss the highly technical aspects of aerospace medicine, I plan to review with you the progress made by NASA in the past year, with special reference to the field of the life sciences. I wish to express my appreciation of the assistance of my colleagues on the NASA staff, particularly to Dr. George M. Knauf, Acting Director of Space Medicine, Office of Manned Space Flight.

We have been fortunate, in the field of biomedical endeavor with which we in NASA are concerned, in having many experienced colleagues in other agencies, and particularly in the United States Air Force, to assist and guide us not only in meeting the practical necessity of evolving a space medicine program but also in defining the scope of this new medical specialty. For such assistance we are grateful to the federal medical

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\$ 1.60 ph.  
\$ 0.80 mf.

community, military and civilian. Their contributions to our program have been not only in the form of advice but in time and manpower and facilities as well. Without these facilities and without the professional interest, skills, and assistance of our colleagues in the federal service, our progress would have been slower.

Today, for the most part, I will talk about the life sciences activities --what the problems and achievements have been, what the problems and programs now are, and what we anticipate for the future. Before this, however, I would like to bring to your attention other NASA programs in which we have accomplished a great deal--our earth satellite programs.

#### THE NASA SATELLITE PROGRAMS

Included in the Scientific Satellites Program are a series of orbiting observatories: the Orbiting Solar Observatory (OSO), the Orbiting Astronomical Observatory (OAO), and the Orbiting Geophysical Observatory (OGO). The first--the Orbiting Solar Observatory--measures continuously the fluctuating solar electromagnetic radiation which is normally obscured by the earth atmosphere. This 450-pound satellite follows a nearly circular 300-mile orbit. The Orbiting Astronomical Observatory, in contrast, weighs nearly 3500 pounds. A stabilized satellite capable of accommodating a variety of astronomical experiments, it also will follow an approximately circular orbit at a 500-mile altitude. It will be launched in 1965. The third observatory--the Orbiting Geophysical Observatory--will be the first of a series of standardized satellites to investigate phenomena in space near the earth--energetic particles, radiation belts, ionospheric phenomena, and magnetic fields. It will also provide detailed study of the unexplored

upper atmosphere above the poles.

A second group of satellites, already familiar to you, are the Weather Satellites. Tiros brings immediately to mind the fact that for the first time in history it is possible to make global observations of cloud patterns which define weather fronts and major storms. This, as you know, is done by means of television cameras and infrared sensors. Nimbus, to be launched within a few months in a near polar orbit, is earth-oriented and hence covers the entire globe with a single satellite.

The third group, equally familiar to the general public and to the scientific community, are the Communications Satellites. Both Telstar I, successfully launched on July 12, 1962, and Relay, the experimental active communications satellite program launched the following December, have pointed toward a global communications system. Syncom, which is in a 24-hour stationary earth orbit, should provide this service with a small number of satellites, reaching, in fact, the entire populations of the earth with three equally spaced satellites.

The unmanned program includes Space Probes, to be launched to explore interplanetary space, the moon, and the nearby planets. Ranger, for example, is the first of a series of spacecraft designed to explore the moon so as to gain greater understanding of the lunar environment before man is landed there.

These, then, are the spacecraft with which the Free World penetrates the environment of space to probe its depths and its potential. In the conduct of the program which has been outlined very briefly, we provide an opportunity for scientists of other countries to participate in the

exploration of space. Today, more than 60 countries take part with NASA in programs of international cooperation--some bilateral, others involving many countries. For example, "Alouette" is a joint Canadian-U.S. satellite launched on September 28, 1962, to study the density of the earth's ionosphere from above by means of radio topside soundings. Other countries participate in the reception of data by telemetry.

Our principal interest today lies in the manned space flight program. As we consider together the biomedical aspects of manned space flight, I would like to recall to you a statement of our late President made two months ago when he dedicated this great national resource, the Aerospace Medical Center:

"Space medicine is still an infant science--but no other frontier of medicine is more exciting. In determining the need and role of various human parts, their creation and their possible substitution, you shall be probing the origins of life itself. And thus, both the ancient past and the distant future--both the beginning and the end of this world and others--may be viewed under the microscopic eye of this and similar schools."

#### THE NASA SPACE MEDICINE PROGRAM

The space medicine program as it now exists in NASA is essentially a product of organizational evolution. There will be many of you who will recall that in our earlier days, as a newly created organization, there was formed an Office of Life Sciences Programs. Some interest in the human element had been evident in the National Advisory Committee for Aeronautics, NASA's predecessor. That organization, in response to problems arising

with the development of high-performance aircraft during World War II, had initiated studies of "human factors" in 1943. However, the National Aeronautics and Space Act of 1958, in stating that "activities in space should be devoted to peaceful purposes for the benefit of all mankind," provided a broader interpretation of the NASA role in the life sciences. In addition to the necessity of investigating the biomedical aspects of survival in space flight, NASA has a significant responsibility for furthering understanding, through studies in the space environment, of the laws of nature as they apply to biology and medicine. NASA, then, in 1960 created, as a fifth major division, the Office of Life Sciences Programs. From the two broad functions just stated, it is evident that the program elements of this office necessarily ranged from applied research to research which was very fundamental in nature.

No government agency of which I am aware attempts to control so wide a range of research under single direct management. Consequently, and also as a result of the organizational realignment and reorganization which is inevitable in the process of growth of a new agency, the Life Sciences Program was divided into three parts. The different parts were assigned to separate offices, appropriate to the character of the research and development undertaken. Basic research was assigned to the Office of Space Science and Applications, under a Director of Bioscience Programs. The responsibility for advanced concepts and systems in the biomedical area was delegated to the Director of Biotechnology and Human Research in the Office of Advanced Research and Technology. Applied research, directly applicable to the approved flight projects, became the responsibility of

the Director of Space Medicine in the Office of Manned Space Flight. Perhaps the point at which to begin this discussion is May 5, 1961.

### Mercury

The flight of Alan B. Shepard, Jr., in MR-3 on that day marked the beginning of manned space flight in America. Its accomplishment followed the qualification of its systems first by unmanned, then by animal flight. MR-3 itself served to qualify both the systems and man for more prolonged flights, thereby laying the original groundwork for all manned space flight endeavors from that time on.

The importance of supplementing our body of scientific information, together with the multiplicity of apprehensions concerning man's welfare when actually exposed to the combined stresses of space flight, prompted the recording of a great many objective and subjective observations throughout the Mercury program.

Bio-instrumentation for the Shepard flight and the second U.S. manned suborbital space flight of Virgil I. Grissom measured respiration by means of a thermistor--temperature rectally--and EKG using a two-lead electrocardiogram. Significant additional data were obtained from numerous very thorough physical examinations, special tests, and laboratory studies both pre- and postflight. It became apparent during the course of the Project Mercury series of flights that a very important index of astronaut performance and well-being was astronaut voice communication. This, coupled with the astronauts' subjective physiological observations, served as a validation of the physiological training which had been given.

Similarly, the outstanding effectiveness of the entire Mercury astronaut team proved to be both a validation of and a tribute to the crew selection methods which were employed. This was evident throughout the Mercury flight series.

With Astronaut John Glenn's first orbital flight came additional improvements, such as the addition of blood pressure to the quantities to be measured. Later in the Mercury series still further improvements were made, such as the replacement of the respiratory thermistor with the impedance pneumograph, the change from rectal to oral temperature, and the addition of tilt-table studies to the postflight medical examination. From the Glenn flight it was learned that disorientation is not a problem of consequence. The later, longer duration flights of Carpenter, Schirra, and Cooper bore this out more firmly.

A trend analysis of Mercury data seems to virtually exclude the presence of acute ill effects due to short-duration weightlessness, but at the same time it also seems to establish that the effects of weightlessness upon man are very probably a function of duration of exposure. It remains for future programs to isolate weightlessness from fatigue, dehydration, and other factors, and to tell us more precisely what limiting factors develop, when they occur, and how they can be corrected.

Project Mercury has been an accomplishment of major proportions. It has proved that man can travel in space without ill effect as well as provide the vehicle for space exploration. It has done much to accomplish the separation of medical fact from medical myth. It has placed the medical problem areas peculiar to space flight in clearer focus. In

doing this, it has prepared the way for Gemini and Apollo, the next two approved manned missions.

### Gemini and Apollo

Projects Gemini and Apollo each represent major milestones in the NASA manned space flight program. Gemini is planned for durations which will extend man's experiences in space flight for periods tenfold over the longest flight we have thus far attained. Man's physiological response to this relatively extended period of weightlessness will be observed closely through the bio-instrumentation already developed and validated. His cardiovascular system will be monitored by the flight EKG and blood pressure instruments, his respiratory function by the impedance pneumograph, and his body temperature by the oral thermometer used for the first time on the Cooper flight. In addition, new flight research instruments, such as the electro-encephalograph, the galvanic skin response indicator, and vibrocardiograph, are being developed and will allow for continued intense observation of additional physiological parameters. These flight measurements, compared with preflight evaluations, baseline data, and intensive postflight examinations, produce data which represent but one aspect of our efforts to expand our knowledge and the fund of medical information which is made available to the world scientific community.

When an astronaut leaves his spacecraft and ventures into free space or moves about on the surface of the moon, the space suit assumes a new importance. This will be especially true when our astronauts explore the surface of the moon. Throughout Project Mercury the full-pressure suit

was utilized as an emergency backup means of protection to insure man's survival in case of an unplanned cabin decompression. Once the astronaut leaves the lunar excursion module and sets foot on the moon, the space suit assumes the role of providing the prime life support to the space explorer. The space suit, with its portable life support system, will protect the astronaut from the hostile environment of space and will provide him with the environment which will enable him not only to survive but to carry out the initial steps of an ever-widening program directed to the scientific exploration of the moon. This lunar exploration, and explorations planned for future missions, is being made possible by an understanding of the physiological responses of man in space, the medical appraisal of these reactions, and the integration of medical and engineering efforts, with the resultant bio-engineering hardware fabricated to sustain man as a functional observer in space.

#### Manned Orbiting Research Laboratory

Project Mercury has given us data and experience on man's exposure to over 34 hours in space. Gemini and Apollo will extend that experience up to periods of 14 days. From a biomedical viewpoint the Manned Orbiting Research Laboratory represents that intermediate step between the lunar-type mission and interplanetary exploration wherein man will be called upon to spend years in space travel.

At this moment it appears that questions which exist regarding man's capacity to adapt to weightlessness, and to tolerate reentry stresses, focus on his cardiovascular and musculoskeletal systems. These systems must be studied in depth; however, it is equally important to assure

ourselves that man as a total system will remain functional and unimpaired. Therefore man in space for extended durations must be observed in totality. His food and water digestion along with the gastro-intestinal system; his breathing along with his respiratory system; his psychomotor functioning along with his central nervous system; these and other human systems performance must be observed and examined in detail. To accomplish such objectives will require the development of new observational techniques and methodologies applicable to space; new and advanced concepts in astronaut selection and training; advances in biotelemetry; and, most of all, the continued utilization of all of our national resources to insure that the challenges presented to us by space will be met and will be conquered.

#### ADVANCED RESEARCH IN THE BIOMEDICAL SCIENCES

The program just discussed is concerned with the biomedical problems of approved projects. As noted, it is the responsibility of the Space Medicine Division of the Office of Manned Space Flight.

To exploit in full the benefit of a scientific investigation of space and our neighboring worlds, man will be required to embark on prolonged and hazardous missions in vehicles that are today called "advanced concepts." How the future astronauts will react to the unnatural and restrictive confinements of space vehicles, how they will be protected from the completely hostile environment, and what the many other physiological and psychological problems will be during these extended flights are among the research objectives of the Biotechnology and Human Research Division in the Office of Advanced Research and Technology.

This division approaches the many problems of prolonged manned space flight on three broad fronts. First, in order that the bioscientist can develop a reasonable set of environmental parameters under which the man can remain "100 percent available and 100 percent effective 100 percent of the time," man is studied both as a member of a crew and as an entity in himself. Each body system response is studied and, wherever required, investigation extends to the cellular level. Man, animals, and even single-celled organisms are subjected to individual and combined space stresses; and all known or conceived methods of psychophysiological assay are used to further our understanding of man's capabilities to live and perform in space.

Once man's psychophysiological response to the space environment and the limits of his performance in it are identified and understood, it remains for the bioscientist and the bio-engineer to utilize this information to provide an adequate life support system and necessary ancillary supportive measures.

Advanced support systems for man require novel approaches to the age-old problems of supplying habitable atmospheres, food, water, adequate waste management, and radiation protection. The second area of endeavor, therefore, is research and development directed toward human support systems which will be compatible with advanced spacecraft systems design and booster capabilities.

As ideas develop into elements of operational equipment and the advanced mission vehicles begin to take shape, a third step is required. Here, the new support systems must be integrated into the overall vehicle

complex. Much of this evaluation and systems integration can be carried on in terrestrial laboratories, where man can be scrutinized, evaluated, and assayed as one segment of the entire system.

Space flight simulation is important in all these studies. However, it probably will be desirable from the point of view of the scientist to precede extended manned space flight by animal experimental flights and later by experiments in orbiting laboratories.

NASA anxiously looks forward to a meaningful biological flight program. This will require the development of bio-instrumentation for the perception and recording of the reactions of test animals and astronauts alike. From present laboratory bio-instrumentation must emerge new and effective monitoring devices and techniques that not only will detect and telemeter vital psychophysiological and environmental information but also will process such information to advise both the vehicle occupant and ground observers of the man's condition through a single indication factor. It is conceived that this computerized situational analyzer will automatically initiate correcting procedures as necessary. This could be in the form of adjusting the ambient environment, administering psychopharmacological agents, or activating an automatic system for vehicle control and navigation or even for mission abort.

Our program in this area is progressing. Eventually, it is hoped that regenerative life support systems will recycle all waste substances into fresh and usable gases, liquids, and foods, and that each atom aboard for the support of man at the onset of the mission will be used many times over before the mission is completed.

## BASIC RESEARCH IN THE LIFE SCIENCES

As indicated at an earlier point in this discussion, the conduct of basic research in the biosciences is delegated to the Bioscience Programs Division. This division is a part of the Office of Space Sciences and Applications.

The stated objective of this office is to apply space technology to basic biological research and to provide biological knowledge that can be of value to the space program. Research is carried on under the headings of Behavioral Biology, Environmental Biology, Exobiology, and Physical Biology.

Behavioral Biology includes four task areas, the first of which uses correlated ground-based and in-flight studies designed to investigate the effects of weightlessness, altered gravity, and other conditions peculiar to the space environment on the behavior of organisms. In another task area, studies include the neural aspects of perception, the cortical representation of perceptual space, mechanisms underlying sensory discrimination, and the complex neuro-behavioral relationships which underlie affective functions and maintain alertness. A third task area is concerned with studies of the principles involved in the acquisition, processing, storage, and retrieval of information in living systems, and the fourth with the experimental analysis of behavior.

Environmental Biology covers five areas of investigation. One of these develops experiments to study the biological effects of such environmental factors of outer space as weightlessness, radiation, and removal from the effects of the earth's rotation. A second area comprises

study in earth-based laboratories of the biological effects of known space environmental factors. These studies will utilize a variety of plants and animals. In the third, studies will be directed toward an understanding of environmental extremes and the physiological and morphological adaptations made by earth organisms living in extreme habitats. Another area will study the effects of simulated lunar and planetary environmental factors on living terrestrial plants and animals to determine which could grow on other planets. The fifth task area is concerned with developing uses of biological organisms for application and exploration in space--for example, organisms for gas exchangers and food supply, to warn of the presence of harmful or toxic agents, or plants to modify planetary atmospheres.

An interesting feature of the environmental biology program is the group of studies planned for orbiting vehicles. These will include the effects of gravity and zero g on living organisms, the biological effects of radiation, and studies of circadian biorhythms.

Investigations in Exobiology represent the third program area. In this program, covered by five task areas, work is being undertaken in evolutionary and theoretical biology, relating to the origin of life, molecular evolution, cellular biochemistry, and the mechanism of cell replication, among others; in the development of instrumentation for detecting extraterrestrial life and life-related compounds; in the spectroscopic analysis of planetary atmospheres and surfaces; in the development of methods for collecting and analyzing extraterrestrial samples; and finally in developing procedures for reducing the number

of bacteria on lunar and Venus probes and for actually sterilizing capsules destined for Martian landing.

The fourth program of the Bioscience Division deals with Physical Biology. Four research areas are included in this program. One is concerned with ground-based research into mechanisms and principles of systemic and general physiology of living organisms, systems, and processes. Another is devoted to the development of new bio-instrumentation for the measurement and analysis of almost every known parameter and for acquiring biological data previously unobtainable. Research to describe biological systems at molecular and cellular levels comprises the third task area. The final task provides for the support of symposia and conferences.

These, then, represent the NASA programs which will be of primary interest to you. They are programs of continuing activity which contribute day-to-day increments to the body of scientific knowledge.

However, there is another area with which we are greatly concerned. It is one in which, during 1963, we feel we have accomplished a great deal, although there is still a long way to go and the need to view it as a continuing activity must always be kept in mind. It is the need for the close coordination of programs between federal agencies engaged in similar activities.

#### INTERAGENCY COORDINATION

I will begin the discussion by stating that whether the specialized area of investigation is designated aviation medicine, aerospace medicine, or space medicine, it is unquestionably medicine. It should come, therefore, as no surprise that where there are a number of government agencies

engaged in medical research programs, they will have laboratories or specialized equipment or facilities which are similar, if not identical. It is obvious to us as scientists that identical equipment or facilities or laboratories necessarily will be found where research in a broad discipline is carried on. It is axiomatic in science that some duplication in experimentation is desirable for verification of the results obtained by a single observer or group.

However, we know through experience that any semblance of duplication in research tasks, any similarity of name in a laboratory, or any duplication in the function of equipment is often interpreted as wasteful or unnecessary duplication when our programs are brought before the public and the Congress. This is understandable, for basic research projects especially are interpreted often, although usually erroneously, as directly applicable to the support of current flight missions rather than as preparation for flight missions of the future.

Although we at NASA Headquarters had felt that there was an excellent exchange of information between our space medicine development personnel at the Manned Spacecraft Center and those at the various installations of the Armed Services, it soon became apparent that a more formal plan of coordination was required. It was obvious that the place to start was with the Air Force, because of its broad program of research and development in the general areas of our interest.

In the spring of 1963, therefore, planning was initiated to accomplish a coordination of tasks in the Fiscal Year 1964 programs. Broad program objectives were reviewed, and small work groups of scientists engaged in

the day-to-day technical management of tasks were established in the areas of crew equipment, environmental control, systems bio-instrumentation, and environmental medicine. These groups reviewed detailed task descriptions to identify common program objectives and plans and available specialized facilities. The approach to the coordination exercise centered about three basic premises. One stated that where active in-house capabilities to meet program objectives were available, the agency having such resources would normally undertake the work planned. The second provided for modification of existing contracts, where modification could be accomplished economically, to meet the technical requirements of both agencies. Finally, in all other instances, every effort would be made to utilize to the greatest degree possible the technical programs and resources of the other agency in developing technical plans and programs. The possibility of duplication was recognized. This was considered justifiable only when the need for alternate or dual approaches could be established as a valid requirement, when the availability of the resource was not consistent with flight program schedules, or when the duplication was essential to maintaining in-house technical proficiency.

In this exercise, 900 tasks were reviewed. Of these, 770 were Air Force. Of the 900 tasks, 375 were identified as unique to the program of the sponsoring agency; 257 were to be continued as planned, with coordination between the two agencies; 34 were cancelled; 111 were set apart for further review; and 123 were determined to require coordination with other elements of NASA or the Air Force. Coordination with the Air Force was completed in September. Coordination with the Army and the Navy was

accomplished through the Department of Defense by submission of detailed task descriptions of the NASA Space Medicine Fiscal Year 1964 Financial Operating Plan to the Director of Defense Research and Engineering for relay to these services. Both the Army and the Navy signed off on the NASA Space Medicine Program in September.

Coordination with the Department of Defense represented a major achievement during this year and, in fact, a noteworthy achievement in the chronology of events in federal medical research and development, for never before has so detailed a comparative evaluation of the research programs of two major agencies of the government been accomplished.

There are, of course, other government agencies with which we must coordinate our program. Among these are the Public Health Service, the Veterans Administration, the Atomic Energy Commission, and the Federal Aviation Agency. Negotiations to this end have been initiated.

We intend to coordinate our Fiscal Year 1965 and subsequent programs with the Department of Defense and the other agencies cited to the degree necessary to provide the most efficient use of related resources in skills, facilities, and dollars.

#### CONCLUSION

To most of the world, the suborbital flights of Shepard and Grissom and the orbital flights of Glenn, Carpenter, Schirra, and Cooper probably represent NASA's most noteworthy achievements. It is likely that human activities in space will continue to be the most interesting facet of our activities as far as the public is concerned, whatever other advances in science we may accomplish.

Certainly these were accomplishments, although from a strictly technical point of view no more so than the development of the communications or weather satellites or the boosters which sent them aloft. Nevertheless, to accomplish these flights within the time we did under the conditions of safety for the astronaut that were imposed was no mean feat, and a major share of the credit may well go to those working in the space medical area, not to just the physicians but also to the engineers and other scientists and technicians from the many disciplines represented in the manned space flight endeavor.

Truly, space medicine is a cooperative effort, not only in terms of the spread of knowledge and skills involved but in the contributions made by other government agencies in related research, specialized facilities, and skilled personnel. In this respect, within the capabilities of the federal government, the past is prologue to a more intensive attempt upon the part of NASA to assure wider coordination of its program within the federal medical research community, more efficient employment in our programs of the equipment, facilities, and skills of other agencies, and through cooperative efforts to achieve the greatest product for the research and development dollars provided. This requires a continuing evaluation of our objectives and a continuing comparison of our programs. Above all, it requires a continuation and strengthening of the will to cooperate which has carried us so far.

I can think of no conclusion more appropriate to any discussion of space research than the words of caution and of inspiration spoken here on November 21, 1963:

"Let us not be carried away with the grandeur of our vision. Many weeks and months and years of long, hard tedious work lie ahead. There will be set-backs and frustrations and disappointments. There will be pressures for our country to do less and temptations to do something else. But this research must and will go on. The conquest of space must and will go ahead. That much we know. That much we can say with confidence and conviction."

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